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(54) **Autostereoscopic directional display apparatus**

Autostereoskopisches Wiedergabegerät

Dispositif d'affichage autostéréoscopique

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(56) References cited:
EP-A- 0 262 955 **EP-A- 0 508 824**
WO-A-83/02169 **WO-A-93/19394**
DE-A- 4 004 739

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Description

[0001] The present invention relates to autostereoscopic directional display apparatuses. Such apparatuses may be used to convert spatial and/or temporal information into directional information, for instance so as to provide an autostereoscopic three dimensional display.

[0002] Known three dimensional (3D) display apparatuses which can create images of opaque moving objects rely on creating the perception of a 3D image to a human observer by displaying a number of two dimensional (2D) images. Each of the 2D images is a view of the object from a particular direction and is "replayed" in that direction. The accuracy and effectiveness of these 3D images and the maximum display size and freedom of viewer location increase as the number of 2D views displayed increases.

[0003] Two known techniques for providing 3D displays use lenticular methods and time multiplexed or sequential methods. For effective operation, such systems must display a large number of 2D views of an object. In direct view lenticular systems, the maximum number of views is determined by the resolution of a spatial light modulator (SLM) used in the system whereas, in multiple projector systems, the maximum number of views is determined by the number of separate SLM's used. In time multiplexed systems, the frame rate of the SLM determines the maximum number of views.

[0004] With known arrangements, to display a large number of views, the maximum frame rates of practical available SLM's are insufficient for time multiplexed displays and the maximum resolution of presently available SLM's is insufficient for direct view lenticular methods. Multiple projector lenticular methods with a large number of SLM's are expensive and bulky. Thus, known 3D display systems are incapable of or inconvenient for accurately providing a moving electronic opaque colour autostereoscopic 3D image from a range of perspectives.

[0005] GB 2 267 579 and EP 0 570 179 discloses time multiplexed and spatially multiplexed systems, and a system which combines spatial and temporal multiplexing to provide a 3D display with a larger number of views. However, the maximum resolution and frame rate of currently available SLM's limit the number of views that can be displayed.

[0006] A known 3D display technique uses a beam combiner and polarising techniques to provide a 3D image which is limited to two views. However, this technique is not autostereoscopic but is stereoscopic, i.e. the observer has to wear polarising glasses in order to see the 3D effect.

[0007] GB 2 185 825A discloses an autostereoscopic display in which two 2D views are imaged by a concave spherical mirror at the eyes of an observer.

[0008] GB 2 066 503A discloses an image projection system which may be used as an autostereoscopic display

by projecting 2D views onto a lenticular screen. Images of the 2D views are formed on the faces of cathode ray tubes and are projected by projection lenses. The projected images are combined by a beam splitter and a mirror and are imaged onto the lenticular screen which provides parallax so that different eyes of an observer see different 2D views.

[0009] GB 2 206 763A discloses a 3D display in which 2D images are supplied in sequence to a SLM. A controlled light source behind the SLM causes each of the 2D images to be visible from a respective direction corresponding to the direction from which the 2D image was captured.

[0010] GB 1 346 915 discloses a directional display device in which arrays of globular lenses are used to permit viewing of spatially multiplexed images in respective directions. By using suitably photographed 2D views and by interlacing elements of the views below the lenses, it is possible to provide an autostereoscopic display.

[0011] GB 1 121 097 discloses a 3D picture which is provided by techniques similar to those disclosed in GB 1 346 915 but using concave reflectors instead of the globular lenses.

[0012] EP 0 262 955A discloses an autostereoscopic display in which images are formed by controllable light sources, for instance in the form of a liquid crystal display (LCD). A lenticular screen is disposed on the LCD to provide parallax so that two 2D views are seen by respective eyes of an observer.

[0013] WO 79/00308 discloses an apparatus for producing a 3D image in which several cathode ray tubes display cross-sections of a scene at different depths. A set of beam splitters and lenses are arranged to stack the 2D images of these cross-sections at different positions along a common optical axis so as to give a representation of a 3D image.

[0014] US 4 623 223 discloses an autostereoscopic display in which two 2D views are reflected by plane mirrors onto a spherical concave mirror.

[0015] WO-A-83 02 169 discloses an apparatus which provides an autostereoscopic display by combining the outputs of two two-dimensional single view displays.

[0016] The concave mirror forms real images of the 2D views which can be viewed by respective eyes of an observer.

[0017] According to a first aspect of the invention, there is provided an autostereoscopic display apparatus as defined in the appended Claim 1.

[0018] Preferred embodiments of the invention are defined in the other appended claims.

[0019] Such an apparatus may be used as a 3D display apparatus to provide a relatively large number of 2D views. Alternatively, such an apparatus may be used in other applications, for instance to provide a sign displaying different information when viewed in different directions.

[0020] It is thus possible to provide optical devices which may be used in direct view display systems and which combine a number of displays of spatially and/or temporally multiplexed type to increase the rate of display of 2D images or views. By increasing the number of views, it is possible to improve the accuracy and appearance of a 3D image. It is also possible to produce a larger range of viewing positions and a large number of separate observers. No viewing aids are necessary to see the 3D effect, i.e. the display is autostereoscopic. Furthermore, known image capture techniques may be used so that colour, movement and opaque images may all be displayed.

[0021] The invention will be further described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a diagrammatic plan view of a 3D display using temporal multiplexing and constituting a first embodiment of the invention;

Figures 2 and 3 are diagrammatic plan views illustrating operation of the display of Figure 1;

Figure 4 is a diagrammatic plan view of a 3D display using spatial multiplexing and constituting a second embodiment of the invention;

Figures 5 and 6 are diagrammatic plan views illustrating operation of the display of Figure 4;

Figures 7 and 8 are diagrammatic plan views of 3D displays using temporal and spatial multiplexing and constituting third and fourth embodiments, respectively, of the invention;

Figures 9 and 10 are diagrammatic plan views of 3D displays constituting fifth and sixth embodiments, respectively, of the invention.

Figure 11 is a diagrammatic plan view of a 3D display using a single illumination arrangement and constituting a seventh embodiment of the invention;

Figure 12 is a diagrammatic plan view of a display of the type shown in Figure 11 modified to form an eighth embodiment of the invention;

Figure 13 is a diagrammatic plan view of a 3D display using folded light paths and constituting a ninth embodiment of the invention;

Figure 14 is a diagrammatic plan view of a 3D display having a compact illumination system and constituting a tenth embodiment of the invention;

Figures 15a to 15c illustrate operation of the display of Figure 14;

Figure 16 illustrates the appearance of tilted viewing windows produced by the display of Figure 11;

Figure 17 is a diagrammatic plan view of a 3D display using a single illumination arrangement and constituting an eleventh embodiment of the invention;

Figure 18 illustrates the appearance of viewing windows produced by the display of Figure 17;

Figure 19 is a diagrammatic plan view of a 3D display using autocollimating screens and constituting a twelfth embodiment of the invention;

Figure 20 is a diagrammatic plan view of a 3D display using angular amplifying screens and constituting a thirteenth embodiment of the invention; and

Figure 21 is a diagrammatic side view of a 3D display constituting a fourteenth embodiment of the invention.

[0022] Like reference numerals refer to like parts throughout the drawings.

[0023] The 3D display shown in Figure 1 comprises a first autostereoscopic display arrangement comprising a plurality of light sources 1 and a control circuit 2 for sequentially illuminating the light sources 1. Four light sources 1 are shown spaced apart laterally with a pitch which is substantially equal to the lateral width of each of the light sources 1. An optical system shown in the drawing as a lens 3 is disposed between the light sources 1 and a spatial light modulator (SLM) 4. Alternatively, the SLM 4 may be disposed between the light sources 1 and the lens 3 and adjacent the lens 3.

[0024] The SLM 4 may comprise a liquid crystal device and is arranged to display a plurality of 2D views in sequence such that each view is illuminated by a respective one of the light sources 1. The 2D views are thus visible from different angles corresponding to the angles at which the views were recorded during image capture.

[0025] The display further comprises a second autostereoscopic display arrangement comprising a plurality of light sources 5, a control circuit 6, a lens 7, and an SLM 8 which are substantially identical to the light sources 1, the control circuit 2, the lens 3, and the SLM 4, respectively.

[0026] The views from the two temporally multiplexed display arrangements are combined by means of an optical combining system shown in the drawing as a beam splitter 9. The views reproduced by the SLM 4 are transmitted through the beam splitter 9 towards an observer 10 whereas the views from the SLM 8 are reflected by the beam splitter 9 towards the observer 10. Figure 2 illustrates the directions in which the views from the two temporally multiplexed display arrangements are pro-

jected towards the beam splitter 9. Figure 3 shows the apparent light source positions and directionality as perceived by the observer 10 via the beam splitter 9. Each 3D image component fills a defined range of image output angles with the components from the two display arrangements being interlaced with each other so that a laterally continuous spread of light emerges from the display. A reconstruction of the 3D image is thus observed over a continuous range of angles by a suitably positioned observer 10.

[0027] The 2D images reproduced by means of the SLM 8 are laterally inverted by the beam splitter 9. Compensation for this may be provided by laterally inverting the 2D views in the SLM 8.

[0028] The beam splitter 9 may comprise any device or system which is capable of performing the optical combining function. For instance, the beam splitter 9 may comprise a partially silvered mirror. Alternatively, in order to reduce the absorption of incident light caused by metallic coatings, all-dielectric non-polarising coatings may be used. However, such coatings are usually designed for particular wavelengths and may thus be of limited application. A hybrid metal-dielectric coating combines the benefits of metals and dielectrics to provide a beam splitter of moderate absorption, low polarisation sensitivity, and good broadband spectral flatness.

[0029] Figure 4 shows a display which comprises two spatially multiplexed display arrangements in place of the temporally multiplexed display arrangements of Figure 1. The SLM's 4 and 8, the beam splitter 9, and the observer 10 correspond to those shown in Figure 1. However, the SLM 4 is illuminated by means of a diffuse light source 11 and the modulated light emerging from the SLM 4 passes through a lenticular screen 12 which comprises a plurality of plano-cylindrical converging lenticules disposed with a regular lateral pitch. Similarly, a diffuse light source 13 and a lenticular screen 14 are provided for the SLM 8.

[0030] Each of the SLM's 4 and 8 simultaneously produces a plurality of interlaced 2D views made up of thin vertical picture elements. A plurality of such picture elements from different views is displayed behind each of the lenticules of the screens 12 and 14 as illustrated in Figure 5. These views are combined by the beam splitter 9 so as to give an apparent picture element position and directionality as illustrated in Figure 6. Thus, as in the embodiment of Figure 1, the reconstructed 3D image is observed over a continuous range of angles by a suitably positioned observer.

[0031] In order to increase the number of available views, the techniques of spatial and temporal multiplexing may be combined as illustrated in the display of Figure 7. The light sources 1 and 5, the control circuits 2 and 6, the lenses 3 and 7, and the beam splitter 9 are the same as shown in Figure 1. However, the SLM's 4 and 8 of Figure 1 are replaced by hybrid sandwiches 20 and 21 of the type disclosed in GB 2 267 579 and EP 0

570 179. For instance, each of the hybrid sandwiches comprises a first lenticular screen having a first lenticular pitch, an SLM, a diffuser, and a second lenticular screen having a second lateral pitch which is greater than the first pitch. The pitch of the second lenticular screen is substantially equal to an integer multiple of the pitch of the first screen.

[0032] The light sources 1 and 5 are illuminated sequentially by the control circuits 2 and 6 and image information is supplied sequentially to the SLM's of the hybrid sandwiches 20 and 21 in synchronism with the illumination. Each "frame" of image information supplied to the SLM's comprises a plurality of images which are spatially multiplexed as described with reference to the embodiment of Figure 4. The individual 2D views are therefore reproduced over angular ranges in directions which correspond to the directions from which the views were recorded during image capture and the beam splitter 9 combines the views so that the observer 10 can observe the 3D image over a continuous range of angles.

[0033] The displays shown in Figures 1 to 7 each comprise a single beam splitter 9 co-operating with two display arrangements to increase the number of 2D views which can be provided to form a composite 3D image. However, a plurality of beam splitters may be provided and the display shown in Figure 8 comprises two beam splitters 9 and 29 with three display arrangements of the combined spatial and temporal multiplexing types shown in Figure 7. The third display arrangement comprises light sources 31, a control circuit 32, a lens 33, and a hybrid sandwich 34 which are substantially identical to the light sources 1, the control circuit 2, the lens 3, and the hybrid sandwich 20, respectively. The views from the hybrid sandwich 20 are transmitted directly through the beam splitters 9 and 29 to the observer 10. The views from the hybrid sandwich 21 are reflected by the beam splitter 9 and transmitted through the beam splitter 29 to the observer 10. The views from the hybrid sandwich 34 are reflected by the beam splitter 29 towards the observer 10. It is therefore possible to provide a larger number of 2D views to form the composite 3D image.

[0034] Figure 9 shows a 3D display of relatively simple type for providing two views. The display of Figure 9 resembles that of Figure 1 but differs in that the light sources 1 and 5 and the control circuits 2 and 6 are replaced by continuously illuminated light sources 41 and 42.

[0035] Figure 10 shows a 3D display which is similar to that of Figure 9 but which includes a further beam splitter 29, lens 43, and SLM 44. The display of Figure 10 has three continuously illuminated light sources 51, 52, and 53 and provides three views. The light sources 51, 52, and 53 are arranged such that the light source 52 is on the axis of the lens 43 whereas the light sources 51 and 53 are displaced from the axes of the lenses 3 and 7, respectively, so that the light beams leaving the

beam splitter 9 are laterally contiguous with each other.

[0036] The display shown in Figure 11 differs from that shown in Figure 1 in that the light sources 5 and the control circuit 6 are omitted and a beam splitting arrangement is provided so as to divide the light from the light sources 1 (only two shown in Figure 11) so as to illuminate both SLM's 4 and 8. Light from the light sources 1 is divided by a beam splitter 56, for instance of the same type as the beam splitter 9, into a transmitted beam and a reflected beam. The transmitted beam is reflected by a mirror 57 towards the lens 3 (for instance of the Fresnel type) and the SLM 4. The reflected beam is reflected by a mirror 58 towards the lens 7 and the SLM 8. The beam splitter 56 is arranged to divide the light into the two beams of equal intensities. The mirrors 57 and 58 are not exactly parallel; one is at a slight angle, for instance approximately 5°, with respect to the other. Thus, each light source 1 gives rise to two apparent light sources being imaged at the eyes of the observer 10 with the appropriate interocular separation therebetween after recombination by the beam splitter 9.

[0037] This arrangement provides a simplified display by eliminating one control circuit and set of light sources. Further, problems associated with matching the light sources 1 and 5 of Figure 1 in terms of colour matching are avoided. The total size and complexity of the display can also be reduced by adopting the single illumination system shown in Figure 11.

[0038] A disadvantage of the display shown in Figure 11 compared with that of Figure 1 is that half the amount of light is provided because half the number of sources are provided. This can be compensated by means of the embodiment shown in Figure 12. The display of Figure 12 differs from that of Figure 11 in that the beam splitter 36 is of the polarising type and divides the light into two orthogonal polarisation components as indicated by the arrows 59 and 60. The SLM's 4 and 8 are of the liquid crystal display (LCD) type incorporating polariser sheets which are arranged to be orthogonal to each other. Further, the beam splitter 9 is of the polarisation sensitive type, so that substantially all of the light propagating through the apparatus is directed towards the observer 10.

[0039] The display shown in Figure 12 can be viewed only from the direction of the observer 10, whereas the display of Figure 11 can also be viewed from the observer position indicated at 10'. For many applications, this is not a disadvantage whereas the increased brightness provided by the display of Figure 12 is an advantage.

[0040] The embodiments of Figures 11 and 12 may be modified by omitting the control circuit 2 and providing a single light source 1 so as to provide two 2D views.

[0041] The display shown in Figure 13 is similar to the display shown in Figure 1 but employs folded light paths for illuminating the SLM's 4 and 8 using mirrors 57 and 58 arranged as shown in Figure 11. The display of Figure 13 further differs from that shown in Figure 1 in that

the light sources 1 and 5 are replaced by diffuse light sources 42 and 44 disposed behind LCD shutters 63 and 64. The shutters are controlled by a control circuit of the type shown at 2 and 6 in Figure 1 and operating in the same way so as to provide effectively a plurality of light sources which are illuminated in turn.

[0042] By folding the light paths from the light sources to the SLM's 4 and 8 as shown in Figure 13, it is possible to provide a relatively compact display. By using two light sources, the brightness of the display can be increased with respect to the display shown in Figure 11.

[0043] The LCD shutters 63 and 65 may be of the ferroelectric liquid crystal, twisted nematic, or super-twisted nematic type so as to provide light of polarisations which match input polarisers of the SLM's 4 and 8, respectively. For instance, the output polarisation of the shutter 63 and the input polarisation of the SLM 4 may be -45° whereas the output polarisation of the shutter 65 and the input polarisation of the SLM 8 may be +45°. Such an arrangement minimises the light loss occurring because of the use of LCD shutters.

[0044] The display shown in Figure 14 resembles that shown in Figure 4 in that it comprises SLM's 4 and 8, a beam combiner 9, diffuse light sources for instance in the form of light boxes 11 and 13, and lenticular screens 12 and 14. However, the display of Figure 14 differs from that of Figure 4 in that the lenticular screens 12 and 14 are disposed between the SLM's 4 and 8 and the light sources 11 and 13 and in that parallax barriers 68 and 69 are disposed in the object planes of the lenticular screens 12 and 14, respectively. In the arrangement shown in Figure 14 employing two SLM's 4 and 8, the parallax barriers 68 and 69 have mark/space ratios of 1:1 i.e. the barriers comprise parallel slits whose widths are equal to the opaque strips defining the slits.

[0045] Operation of the display shown in Figure 14 is illustrated in Figures 15a to 15c. Figure 15a illustrates the light beams 70 produced by a typical lenticule of the screen 12. Light emanating from four of the slits of the parallax barrier 68 adjacent the lenticule are imaged by the lenticule at observer locations. Figure 15b is a similar view showing the light beams 71 produced by the lenticular screen 14. Again, the slits of the barrier 69 are imaged at observer locations.

[0046] The positions of the slits of the parallax barriers 68 and 69 in relation to the lenticular screens 12 and 14 are such that the beam combiner 9 produces a light output pattern as illustrated in Figure 15c. Thus, the light beams 70 and 71 are interlaced with each other and the slits of the parallax barriers 68 and 69 are imaged at the observer locations with an effective pitch 72 equal to the average interocular separation.

[0047] The illumination system of the display of Figure 14 is compact and therefore permits a relatively compact display to be provided. Further, the design of the lenticular screens 12 and 14 is substantially independent of that of the SLM's 4 and 8. In particular, the pitches of the lenticules of the screens 12 and 14 may be much

greater than the pitches of the pixels of the SLM's 4 and 8, thus relieving potential problems with Moire fringing, loss of alignment, and manufacturing tolerances of the lenticular screens. For example, the lenticular screens may have a pitch of 3 mm and the parallax barriers may have a pitch of nominally 3 mm with 1.5 mm black stripes spaced in the object plane of the screens such that an image of each parallax barrier is formed at the observer 10. The actual pitch of the parallax barrier is controlled so that "windows" are generated at the observer 10 from the entire screen.

[0048] As in the case of the other embodiments of the invention, the lenticular screens may be replaced by microlens screens to provide both vertical and horizontal parallax.

[0049] The display shown in Figure 11 has a single illumination arrangement, which may comprise one light source 1 as shown in Figure 17 or a plurality of light sources as shown in Figure 11, and together with the beam splitter 36 generates two apparent illumination arrangements. The images of the illumination arrangements have to be split in order for the observer 10 to see two "windows", each modulated by a respective SLM 4 or 8. The arrangement shown in Figure 11 achieves this by providing relative tilts between the mirrors 37 and 38. However, such an arrangement provides windows as shown at 75 and 76 for the left and right eyes of the observer in Figure 16. The windows 75 and 76 abut at one height, above which they overlap and below which there is a dark space therebetween. This can cause unwanted artifacts in the perceived 3D image.

[0050] Figure 17 shows a display which is similar to that shown in Figure 11. However, the display of Figure 17 provides a single light source 1 and each of the SLM's 4 and 8 provides a single view. Further, the mirrors 57 and 58 are parallel to each other. In Figure 11, the axis of each lens 3 and 7 and the axis of the respective display coincide. However, in the display of Figure 17, the axis 77 of the lens 3 is laterally displaced from the display axis 78 and the axis 79 of the lens 7 is laterally displaced from the display axis 80 in order to split the images of the illuminator 1 at the observer 10. This provides windows 81 and 82 which, as shown in Figure 18, are parallel to each other and, by appropriate choice of geometry, can be made to be contiguous along their adjacent edges 83.

[0051] Although the display of Figure 17 has a single light source 1 and provides two views, it may have a plurality of light sources and provide more than two views as in the case of the display of Figure 11. Similarly, the display of Figure 11 may be modified to have a single light source and to provide two views.

[0052] Figures 19 and 20 show displays of the type shown in Figure 9 but which the lenses 3 and 7 replaced by alternative optical elements. In the display of Figure 19, the lenses are replaced by autocollimating screens 85 and 86. Each autocollimating screen comprises an array of lenticules or microlenses of equal focal length.

In particular, the screens 85 and 86 each comprise first and second lenticular screens or microlens arrays having plain surfaces which abut against each other and with the focal lengths of the lenticules or lenses being the same. Thus, the autocollimating screens 85 and 86 are optically equivalent to the lenses 3 and 7 in the display of Figure 9. Accordingly, the windows 87 produced by imaging the light sources 41 and 42 at the observer 10 are of substantially the same size as the light sources 41 and 42.

[0053] In the display shown in Figure 20, the autocollimating screens are replaced by angular amplifying screens 88 and 89. Each of the screens 88 and 89 comprises first and second screens of the same types as for the screens 85 and 86 in Figure 19, but with the screen nearer the respective light source having a larger focal length than that of the screen nearer the SLM. The effect of substituting the angular amplifying screens 88 and 89 for the autocollimating screens 85 and 86 is to produce windows 90 at the observer which are larger than the light sources 41 and 42.

[0054] Each of the screens 85, 86, 88, and 89 may have a diffuser located between the arrays of lenses or lenticules. Also, the light sources 41 and 42 may be replaced by a plurality of light sources of the type shown at 1 and 5 in Figure 1 and the SLM's 4 and 8 may provide temporarily multiplexed views. Further, the autocollimating screens or angular amplifying screens may be substituted in place of the lenses 3 and 7 in any of the other embodiments described herein and shown in the accompanying drawings. The use of angular amplifying screens allows the use of smaller light sources or smaller illumination shutter SLM's where such devices define the light sources, and may have advantages in terms of cost and compactness.

[0055] The display shown in Figure 21 is of the same type as the display shown in Figure 9. However, the display of Figure 21 differs in the orientation of the various elements. Thus, the SLM 4 is arranged vertically whereas the SLM 8 is arranged horizontally, as opposed to the display of Figure 9 and all of the other embodiments in which the SLM's are all arranged vertically. Similarly, one or more of the SLM's in all of the other embodiments may be arranged horizontally, should such a configuration be preferable in any application.

[0056] Displays of the type shown in the drawings may be used in 3D television, 3D computer aided design and graphics, 3D medical imaging, virtual reality, and computer games. By providing an increased number of 2D views to make up the 3D image, the accuracy and effectiveness of the 3D images can be increased and the maximum display sizes and freedom of viewer location can be increased. Further, moving opaque colour autostereoscopic 3D images from a range of perspectives may be reproduced.

Claims

1. An autostereoscopic directional display apparatus comprising a plurality of displays and an optical combining system (9, 29) for combining outputs of the displays, characterised in that each of the displays comprises an autostereoscopic display and co-operates with the optical combining system (9, 29) to provide a plurality of views which are visible in respective different directions.
2. An apparatus as claimed in Claim 1, characterised in that each of the directions in which the views are visible comprises an angular range.
3. An apparatus as claimed in Claim 2, characterised in that the angular ranges are angularly contiguous in a lateral plane.
4. An apparatus as claimed in any one of the preceding claims, in that the directions in which the views provided by each of the displays and the optical combining system (9, 29) are visible are different from the directions in which the views provided by the or each other of the displays and the optical combining system (9, 29) are visible.
5. An apparatus as claimed in Claim 4, characterised in that the directions in which the views provided by each of the displays are visible are interlaced with the directions in which the views provided by the or each other of the displays are visible.
6. An apparatus as claimed in any one of the preceding claims, characterised in that each of the displays comprises a temporally multiplexed display.
7. An apparatus as claimed in Claim 6, characterised in that each of the displays comprises a spatial light modulator (4, 8), an optical system (3, 7), and a plurality of sequentially illuminatable light sources (1, 5) arranged to illuminate the spatial light modulator (4, 8) at respective different angles via the optical system (3, 7).
8. An apparatus as claimed in any one of Claims 1 to 5, characterised in that each of the displays comprises a spatially multiplexed display.
9. An apparatus as claimed in Claim 8, characterised in that each of the displays comprises a spatial light modulator (4, 8), a diffuse light source (11, 13) for illuminating the spatial light modulator (4, 8), and an array of lenses (12, 14) or a parallax barrier disposed between the spatial light modulator (4, 8) and the optical combining system (9, 29).
10. An apparatus as claimed in Claim 9, characterised in that each of the arrays of lenses comprises a lenticular screen (12, 14).
11. An apparatus as claimed in any one of Claims 1 to 5, characterised in that each of the displays comprises a temporally and spatially multiplexed display.
12. An apparatus as claimed in Claim 11, characterised in that each of the displays comprises a spatial light modulator, a first array of lenses or a first parallax barrier having a first pitch disposed adjacent a first side of the spatial light modulator, a second array of lenses or a second parallax barrier having a second pitch greater than the first pitch disposed adjacent a second side of the spatial light modulator between the spatial light modulator and the optical combining system (9, 29), an optical system (3, 7), and a plurality of sequentially illuminatable light sources (1, 5) arranged to illuminate the first array of lenses or the first parallax barrier at respective different angles via the optical system (3, 7).
13. An apparatus as claimed in Claim 7 or 12, characterised by beam splitting means (56, 57, 58) disposed between the light sources (1), which are common to the displays, and the spatial light modulators (4, 8).
14. An apparatus as claimed in Claim 13, characterised in that the beam splitting means comprises a beam splitter (56) for splitting light from the light sources (1) into a plurality of beams and a plurality of mirrors (57, 58), each of which is arranged to reflect a respective beam towards a respective one of the spatial light modulators (4, 8).
15. An apparatus as claimed in Claim 14, characterised in that the beam splitter (56) and the optical combining system (9, 29) are polarisation-sensitive so that substantially all of the light from the beam splitter (56) is supplied by the optical combining system (9, 29) to a single observer region.
16. An apparatus as claimed in Claim 7 or 12, characterised in that the light sources of each of the displays comprise a diffuse light source (42, 44) disposed behind respective shutters (43, 45).
17. An apparatus as claimed in Claim 16, characterised in that the light paths from the shutters (63, 65) cross each other and intersect respective mirrors (57, 58) arranged to reflect light towards the respective spatial light modulators (4, 8).
18. An apparatus as claimed in Claim 16 or 17, characterised in that each of the shutters (63, 65) has an output polarisation which matches an input polarisation.

sation of the respective spatial light modulator (4, 8).

19. An apparatus as claimed in any one of the preceding claims, characterised in that the optical combining system (9, 29) comprises at least one beam combiner having an optically transmissive path and an optically reflective path.

Patentansprüche

1. Autostereoskopische Richtungs-Anzeigevorrichtung mit einer Anzahl von Anzeigen und einem optischen Kombiniersystem (9, 29) zum Kombinieren der Ausgangssignale der Anzeigen, **dadurch gekennzeichnet**, dass jede der Anzeigen eine autostereoskopische Anzeige umfasst und mit dem optischen Kombiniersystem (9, 29) zusammenwirkt, um für mehrere Ansichten zu sorgen, die in jeweils verschiedenen Richtungen erkennbar sind.
2. Vorrichtung nach Anspruch 1, **dadurch gekennzeichnet**, dass jede der Richtungen, in denen die Anzeigen erkennbar sind, einen Winkelbereich umfasst.
3. Vorrichtung nach Anspruch 2, **dadurch gekennzeichnet**, dass die Winkelbereiche in einer sich in Querrichtung erstreckenden Ebene winkelmäßig zusammenhängen.
4. Vorrichtung nach einem der vorstehenden Ansprüche, **dadurch gekennzeichnet**, dass die Richtungen, in denen die Ansichten erkennbar sind, wie sie von jeder der Anzeigen und dem optischen Kombiniersystem (9, 29) erzeugt werden, von denjenigen Richtungen verschieden sind, in denen die Ansichten erkennbar sind, die von der Anzeige oder jeder der anderen Anzeigen und dem optischen Kombiniersystem (9, 29) erzeugt werden.
5. Vorrichtung nach Anspruch 4, **dadurch gekennzeichnet**, dass die Richtungen, in denen die von jeder der Anzeigen erzeugten Ansichten erkennbar sind, mit denjenigen Richtungen verschachtelt sind, in denen die durch die Anzeige oder jede der anderen Anzeige erzeugten Ansichten erkennbar sind.
6. Vorrichtung nach einem der vorstehenden Ansprüche, **dadurch gekennzeichnet**, dass jede der Anzeigen eine im Zeitmultiplex betriebene Anzeige ist.
7. Vorrichtung nach Anspruch 6, **dadurch gekennzeichnet**, dass jede der Anzeigen einen Raumlichtmodulator (4, 8), ein optisches System (3, 7) und mehrere sequentiell einschaltbare Lichtquellen (1, 5), die so angeordnet sind, dass sie den Raumlicht-

modulator (4, 8) über das optische System (3, 7) unter jeweils verschiedenen Winkeln beleuchten, aufweist.

8. Vorrichtung nach einem der Ansprüche 1 bis 5, **dadurch gekennzeichnet**, dass jede der Anzeigen eine im Raummultiplex betriebene Anzeige ist.
9. Vorrichtung nach Anspruch 8, **dadurch gekennzeichnet**, dass jede der Anzeigen einen Raumlichtmodulator (4, 8), eine diffuse Lichtquelle (11, 13) zum Beleuchten des Raumlichtmodulators (4, 8) und eine Anordnung von Linsen (12, 14) oder eine Parallaxesperre, die zwischen dem Raumlichtmodulator (4, 8) und dem optischen Kombiniersystem (9, 29) angeordnet ist, aufweist.
10. Vorrichtung nach Anspruch 9, **dadurch gekennzeichnet**, dass jede der Anordnungen von Linsen ein Rasterlinsenschirm (12, 14) ist.
11. Vorrichtung nach einem der Ansprüche 1 bis 5, **dadurch gekennzeichnet**, dass jede der Anzeigen eine im Zeit- und Raummultiplex betriebene Anzeige ist.
12. Vorrichtung nach Anspruch 11, **dadurch gekennzeichnet**, dass jede der Anzeigen einen Raumlichtmodulator, eine erste Anordnung von Linsen oder eine erste Parallaxesperre mit einer ersten Schrittweite, die angrenzend an eine erste Seite des Raumlichtmodulators angeordnet sind, eine zweite Anordnung von Linsen oder eine zweiten Parallaxesperre mit einer zweiten Schrittweite über der ersten Schrittweite, die angrenzend an eine zweite Seite des Raumlichtmodulators zwischen dem Raumlichtmodulator und dem optischen Kombiniersystem (9, 29) angeordnet sind, ein optisches System (3, 7) und eine Anzahl sequentiell einschaltbarer Lichtquellen (1, 5), die so angeordnet sind, dass sie die erste Anordnung von Linsen oder die erste Parallaxesperre unter jeweils verschiedenen Winkeln über das optische System (3, 7) beleuchten, aufweist.
13. Vorrichtung nach Anspruch 7 oder 12, **gekennzeichnet durch** eine Strahlteilereinrichtung (56, 57, 58), die zwischen den Lichtquellen (1), die den Anzeigen gemeinsam sind, und den Raumlichtmodulatoren (4, 8) angeordnet ist.
14. Vorrichtung nach Anspruch 13, **dadurch gekennzeichnet**, dass die Strahlteilereinrichtung einen Strahlteiler (56) zum Aufteilen des Lichts von den Lichtquellen (1) in mehrere Strahlen sowie mehrere Spiegel (57, 58) aufweist, von denen jeder so angeordnet ist, dass er einen jeweiligen Strahl zu einem jeweiligen der Raumlichtmodulatoren (4, 8) re-

flektiert.

15. Vorrichtung nach Anspruch 14, **dadurch gekennzeichnet**, dass der Strahlteiler (56) und das optische Kombiniersystem (9, 29) polarisationsempfindlich sind, so dass im wesentlichen das gesamte Licht des Strahlteilers (56) durch das optische Kombiniersystem (9, 29) in einen einzelnen Betrachterbereich geliefert wird.

16. Vorrichtung nach Anspruch 7 oder 12, **dadurch gekennzeichnet**, dass die Lichtquellen jeder der Anzeigen eine diffuse Lichtquelle (42, 44) aufweisen, die hinter jeweiligen Verschlüssen (43, 45) angeordnet ist.

17. Vorrichtung nach Anspruch 16, **dadurch gekennzeichnet**, dass die Lichtpfade von den Verschlüssen (63, 65) einander schneiden und jeweilige Spiegel (57, 58) kreuzen, die so angeordnet sind, dass sie Licht zu den jeweiligen Raumlichtmodulatoren (4, 8) reflektieren.

18. Vorrichtung nach Anspruch 16 oder 17, **dadurch gekennzeichnet**, dass jeder der Verschlüsse (63, 65) eine Ausgangspolarisation aufweist, die an die Eingangspolarisation des jeweiligen Raumlichtmodulators (4, 8) angepasst ist.

19. Vorrichtung nach einem der vorstehenden Ansprüche, **dadurch gekennzeichnet**, dass das optische Kombiniersystem (9, 29) mindestens einen Strahlkombinierer mit einem optischen Transmissionspfad und einem optischen Reflexionspfad aufweist.

Revendications.

1. Appareil d'affichage directionnel autostéréoscopique comprenant une multiplicité de dispositifs d'affichage et un système de combinaison optique (9, 29) pour combiner les sorties des dispositifs d'affichage, caractérisé en ce que chacun des dispositifs d'affichage comprend un dispositif d'affichage autostéréoscopique et coopère avec le système de combinaison optique (9, 29) pour fournir une multiplicité de vues qui sont visibles dans différentes directions respectives.

2. Appareil selon la revendication 1, caractérisé en ce que chacune des directions dans lesquelles les vues sont visibles comprend une plage angulaire.

3. Appareil selon la revendication 2, caractérisé en ce que les plages angulaires sont contiguës du point de vue angulaire dans un plan latéral.

4. Appareil selon l'une quelconque des revendications

précédentes, caractérisé en ce que les directions dans lesquelles les vues fournies par chacun des dispositifs d'affichage et le système de combinaison optique (9, 29) sont visibles diffèrent des directions dans lesquelles les vues fournies par le dispositif d'affichage ou chacun des autres dispositifs d'affichage et le système de combinaison optique (9, 29) sont visibles.

5. Appareil selon la revendication 4, caractérisé en ce que les directions dans lesquelles les vues fournies par chacun des dispositifs d'affichage sont visibles sont entrelacées avec les directions dans lesquelles les vues fournies par le dispositif d'affichage ou chacun des autres dispositifs d'affichage sont visibles.

6. Appareil selon l'une quelconque des revendications précédentes, caractérisé en ce que chacun des dispositifs d'affichage comprend un dispositif d'affichage à multiplexage temporel.

7. Appareil selon la revendication 6, caractérisé en ce que chacun des dispositifs d'affichage comprend un dispositif de modulation spatiale de lumière (4, 8), un système optique (3, 7) et une multiplicité de sources de lumière à éclairage séquentiel (1, 5) qui sont disposées de façon à éclairer le dispositif de modulation spatiale de lumière (4, 8) suivant différents angles respectifs via le système optique (3, 7).

8. Appareil selon l'une quelconque des revendications 1 à 5, caractérisé en ce que chacun des dispositifs d'affichage comprend un dispositif d'affichage à multiplexage spatial.

9. Appareil selon la revendication 8, caractérisé en ce que chacun des dispositifs d'affichage comprend un dispositif de modulation spatiale de lumière (4, 8), une source de lumière diffuse (11, 13) servant à éclairer le dispositif de modulation spatiale de lumière (4, 8) et une rangée de lentilles (12, 14) ou une barrière parallaxique disposée entre le dispositif de modulation spatiale de lumière (4, 8) et le système de combinaison optique (9, 29).

10. Appareil selon la revendication 9, caractérisé en ce que chacune des rangées de lentilles comprend un écran lenticulaire (12, 14).

11. Appareil selon l'une quelconque des revendications 1 à 5, caractérisé en ce que chacun des dispositifs d'affichage comprend un dispositif d'affichage à multiplexage spatial et à multiplexage temporel.

12. Appareil selon la revendication 11, caractérisé en ce que chacun des dispositifs d'affichage comprend un dispositif de modulation spatiale de lumière, une

- première rangée de lentilles ou une première barrière parallactique présentant un premier pas, disposée de façon adjacente à un premier côté du dispositif de modulation spatiale de lumière, une seconde rangée de lentilles ou une seconde barrière parallactique présentant un second pas supérieur au premier pas, disposée de façon adjacente à un second côté du dispositif de modulation spatiale de lumière, entre le dispositif de modulation spatiale de lumière et le système de combinaison optique (9, 29), un système optique (3, 7) et une multiplicité de sources de lumière à éclairage séquentiel (1, 5) disposées de façon à éclairer la première rangée de lentilles ou la première barrière parallactique suivant différents angles respectifs via le système optique (3, 7).
13. Appareil selon la revendication 7 ou la revendication 12, caractérisé par des moyens de division de faisceau (56, 57, 58) disposés entre les sources de lumière (1), qui sont communes aux dispositifs d'affichage, et les dispositifs de modulation spatiale de lumière (4, 8).
14. Appareil selon la revendication 13, caractérisé en ce que le moyen de division de faisceau comprend un diviseur de faisceau (56) servant à diviser la lumière en provenance des sources de lumière (1) en une multiplicité de faisceaux, et une multiplicité de miroirs (57, 58), chaque miroir étant disposé de façon à réfléchir un faisceau respectif en direction d'un dispositif respectif parmi les dispositifs de modulation spatiale de lumière (4, 8).
15. Appareil selon la revendication 14, caractérisé en ce que le diviseur de faisceau (56) et le système de combinaison optique (9, 29) sont sensibles à la polarisation si bien que pratiquement toute la lumière en provenance du diviseur de faisceau (56) est fournie par le système de combinaison optique (9, 29) à une région d'observation unique.
16. Appareil selon la revendication 7 ou la revendication 12, caractérisé en ce que les sources de lumière de chacun des dispositifs d'affichage comprend une source de lumière diffuse (42, 44) disposée derrière des obturateurs respectifs (43, 45).
17. Appareil selon la revendication 16, caractérisé en ce que les trajets de lumière en provenance des obturateurs (63, 65) se croisent entre eux et intersectent des miroirs respectifs (57, 58) disposés de façon à réfléchir la lumière en direction des dispositifs de modulation spatiale de lumière respectifs (4, 8).
18. Appareil selon la revendication 16 ou la revendication 17, caractérisé en ce que chacun des obturateurs (63, 65) présente une polarisation de sortie qui coïncide avec une polarisation d'entrée du dispositif de modulation spatiale de lumière respectif (4, 8).
19. Appareil selon l'une quelconque des revendications précédentes, caractérisé en ce que le système de combinaison optique (9, 29) comprend au moins un dispositif de combinaison de faisceau présentant un trajet de transmission optique et un trajet de réflexion optique.

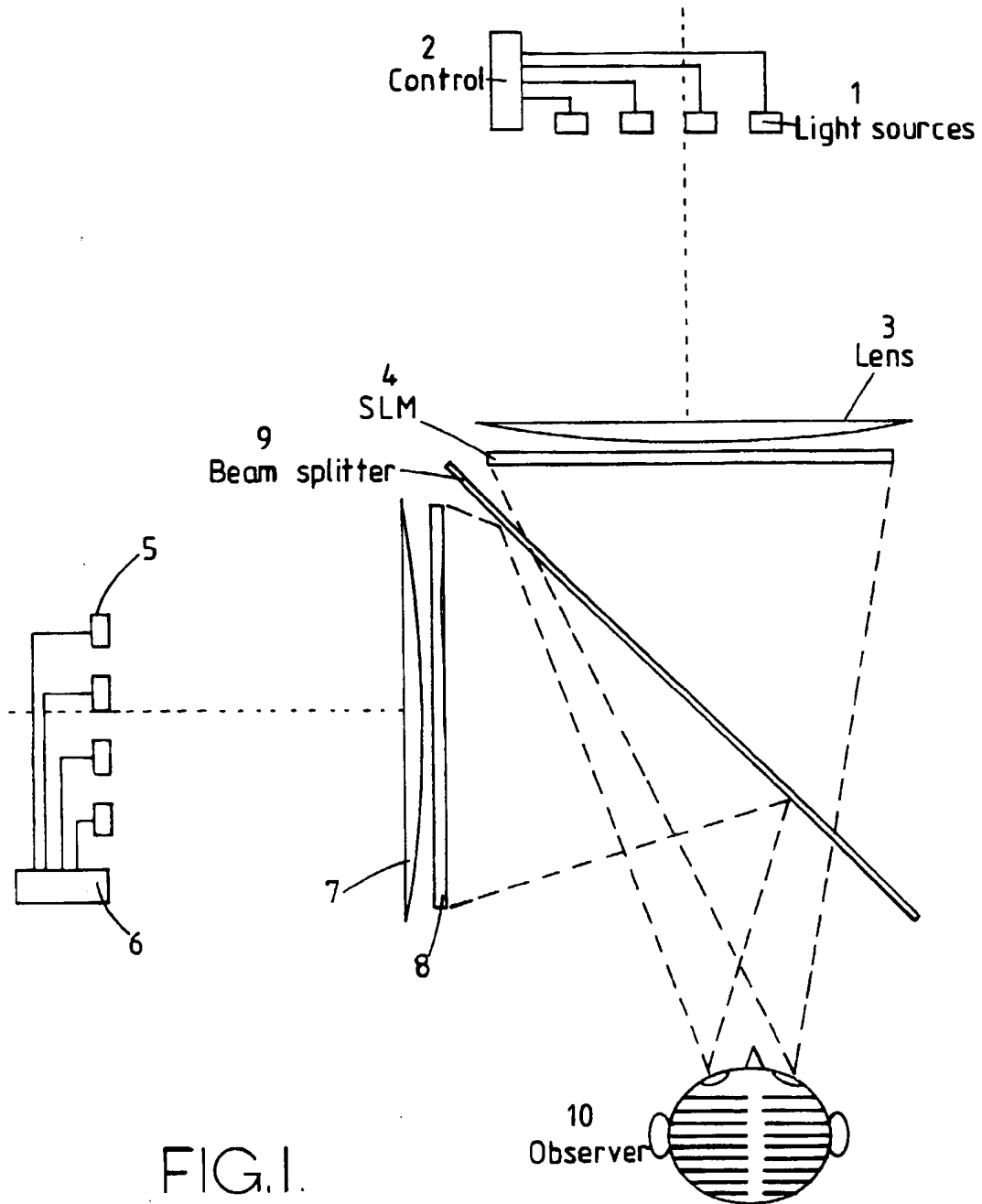


FIG.1.

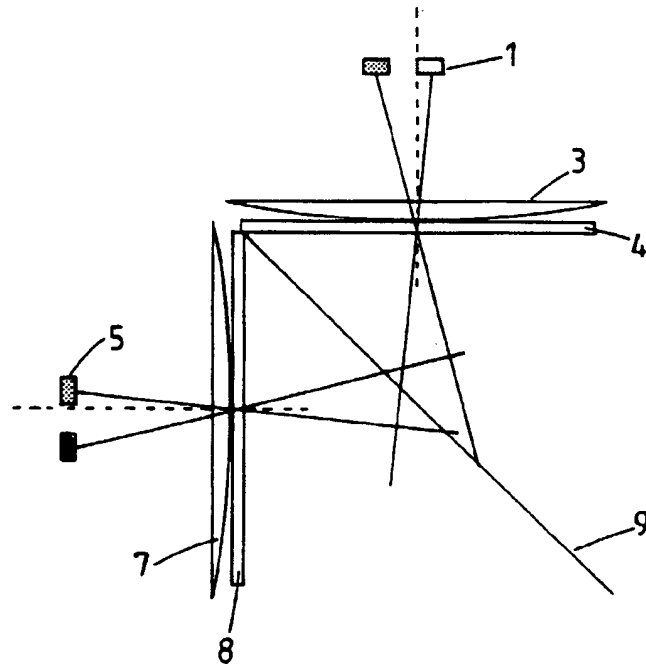


FIG.2.

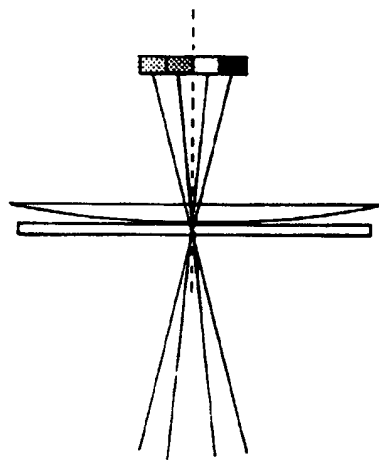


FIG.3.

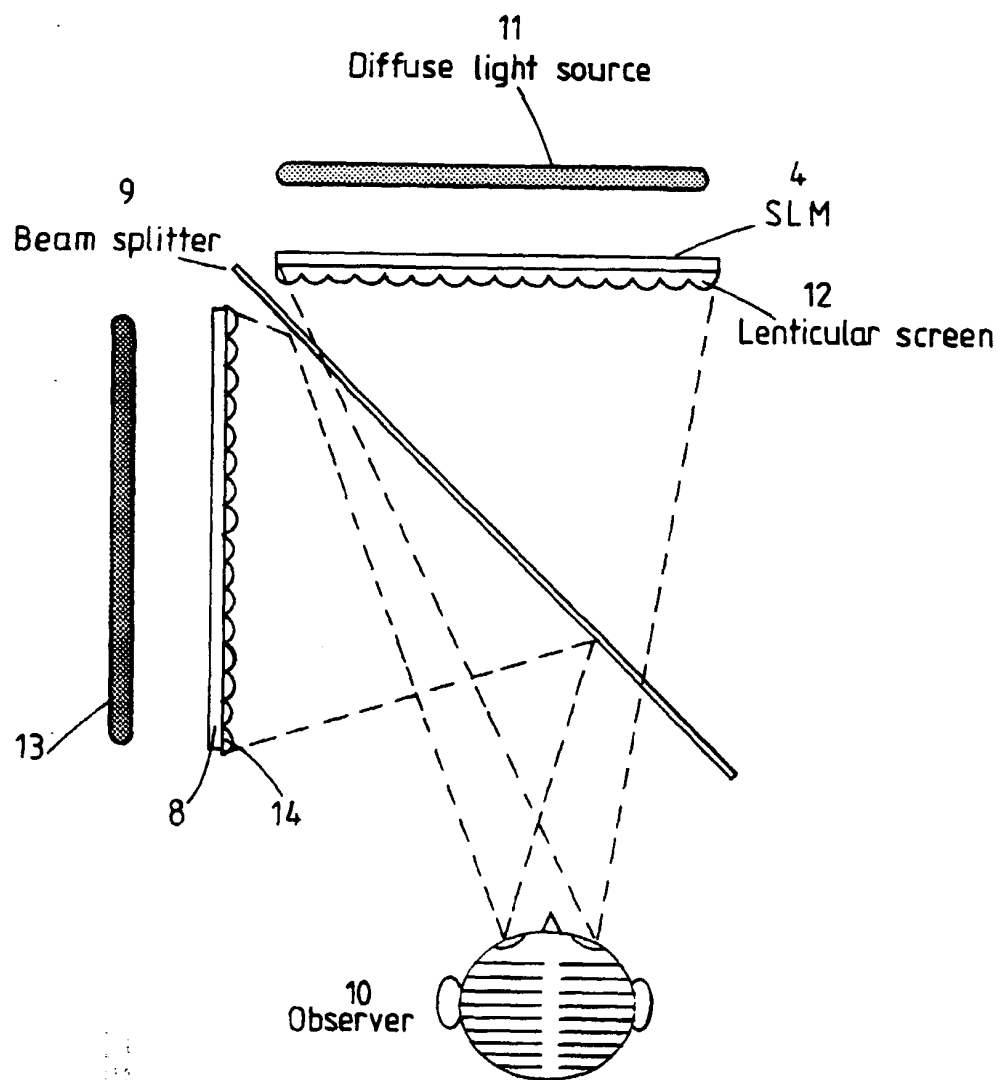


FIG.4.

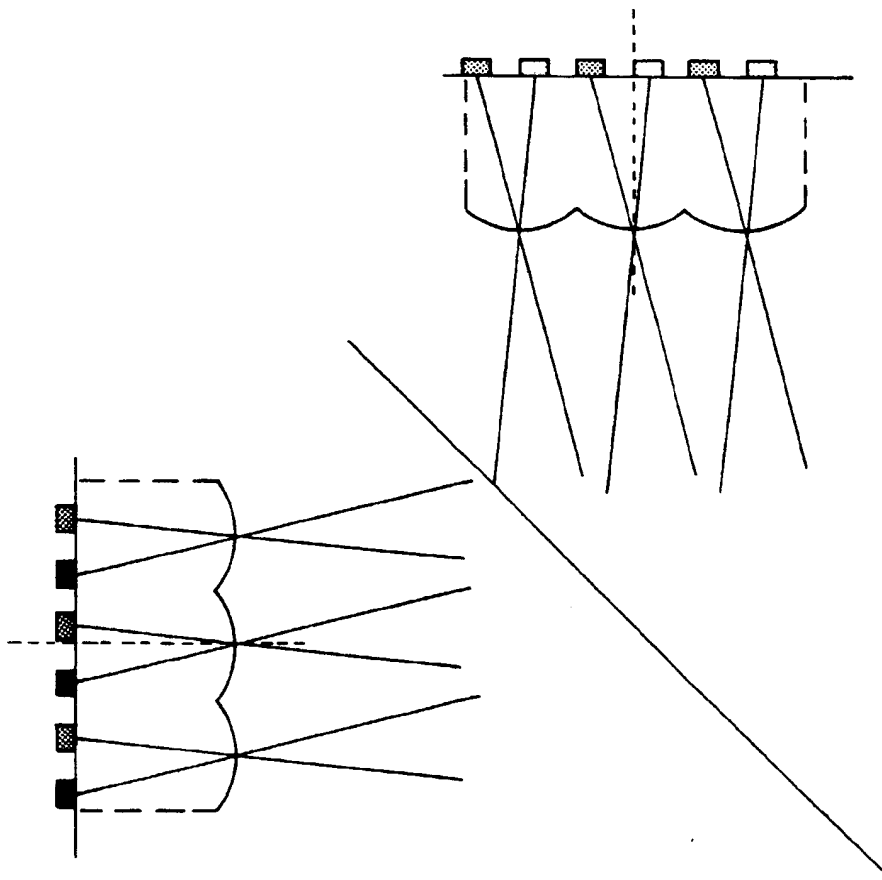


FIG.5.

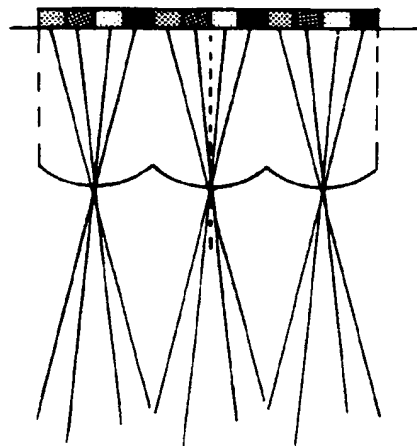


FIG.6.

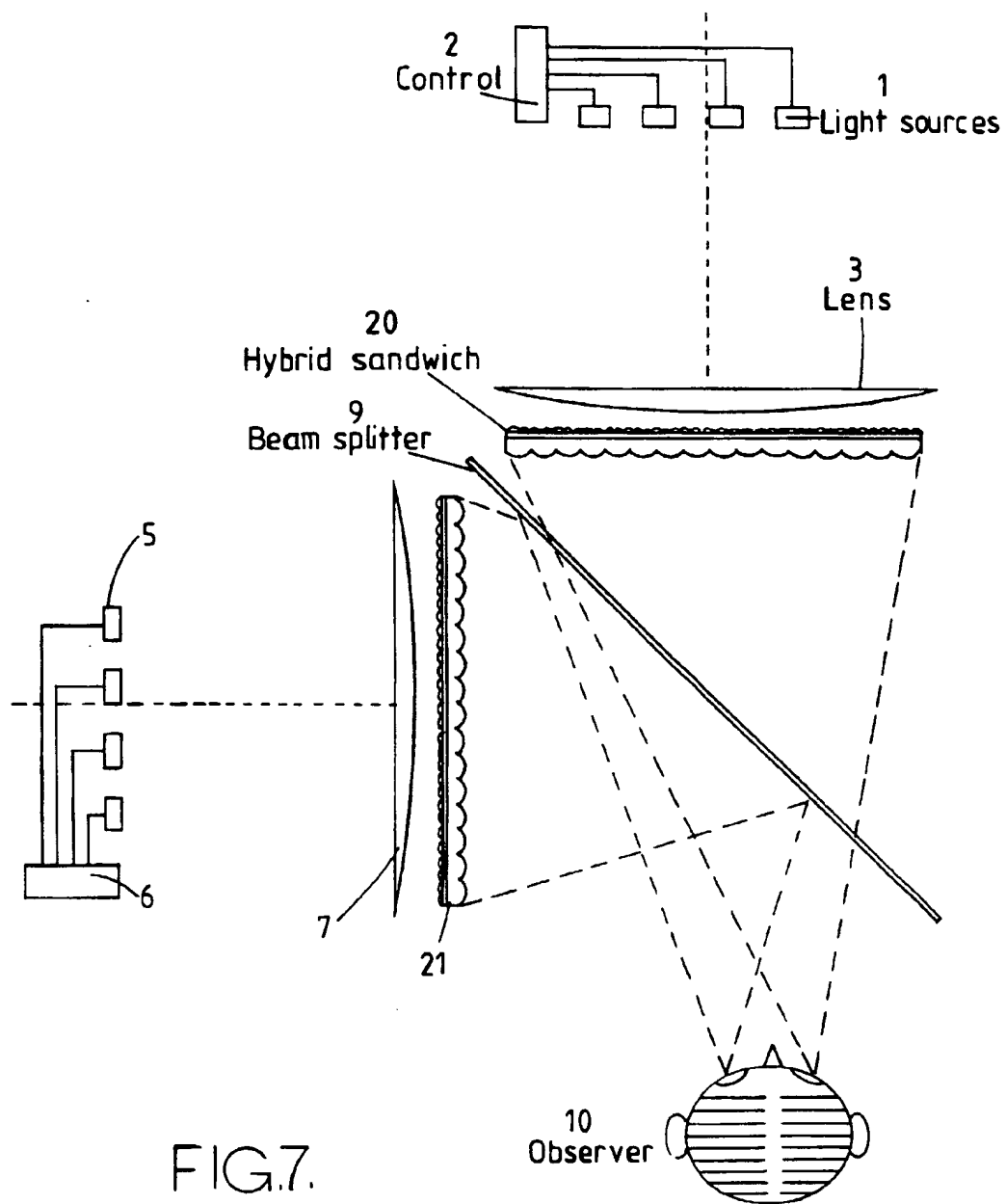


FIG.7.

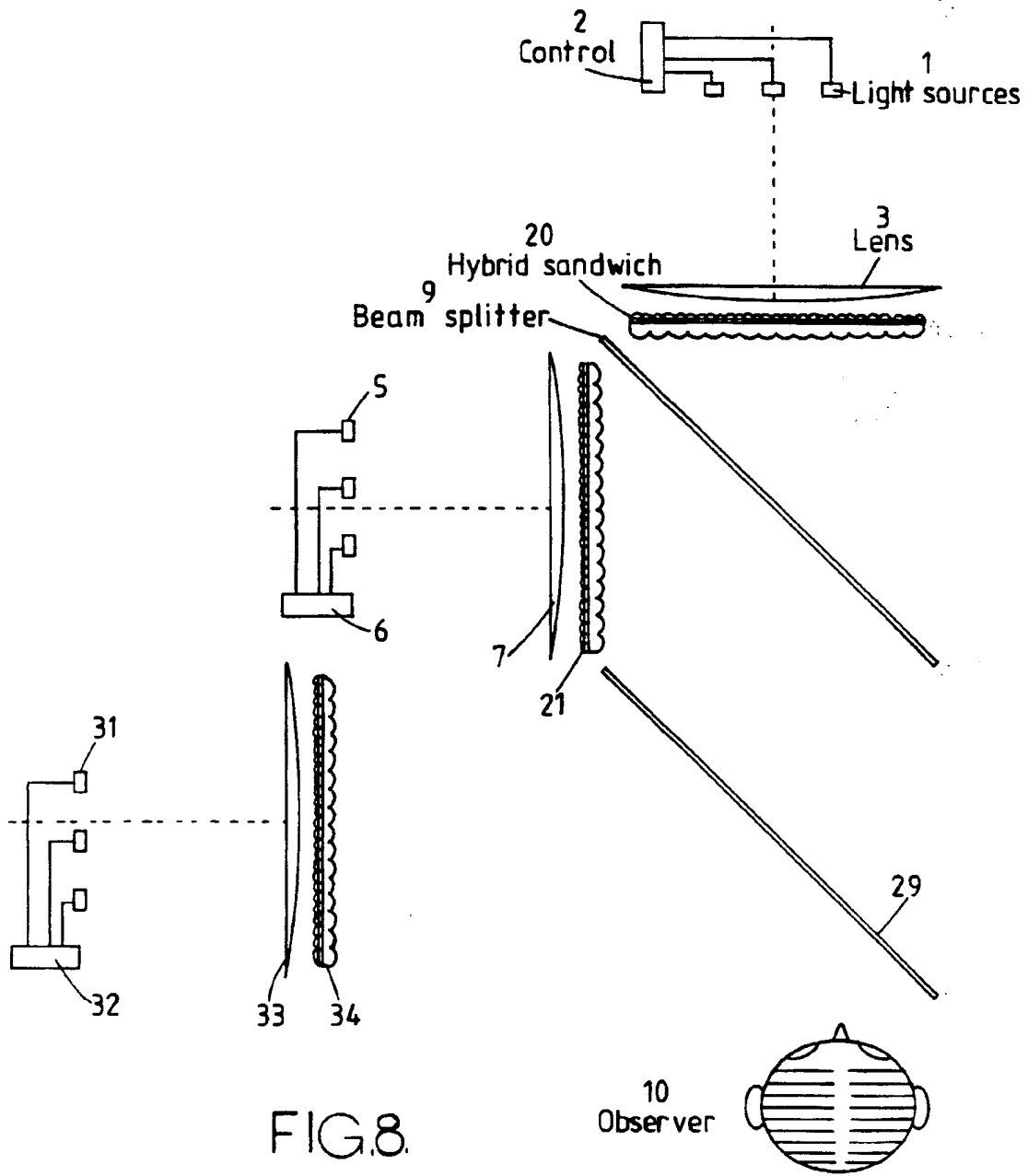
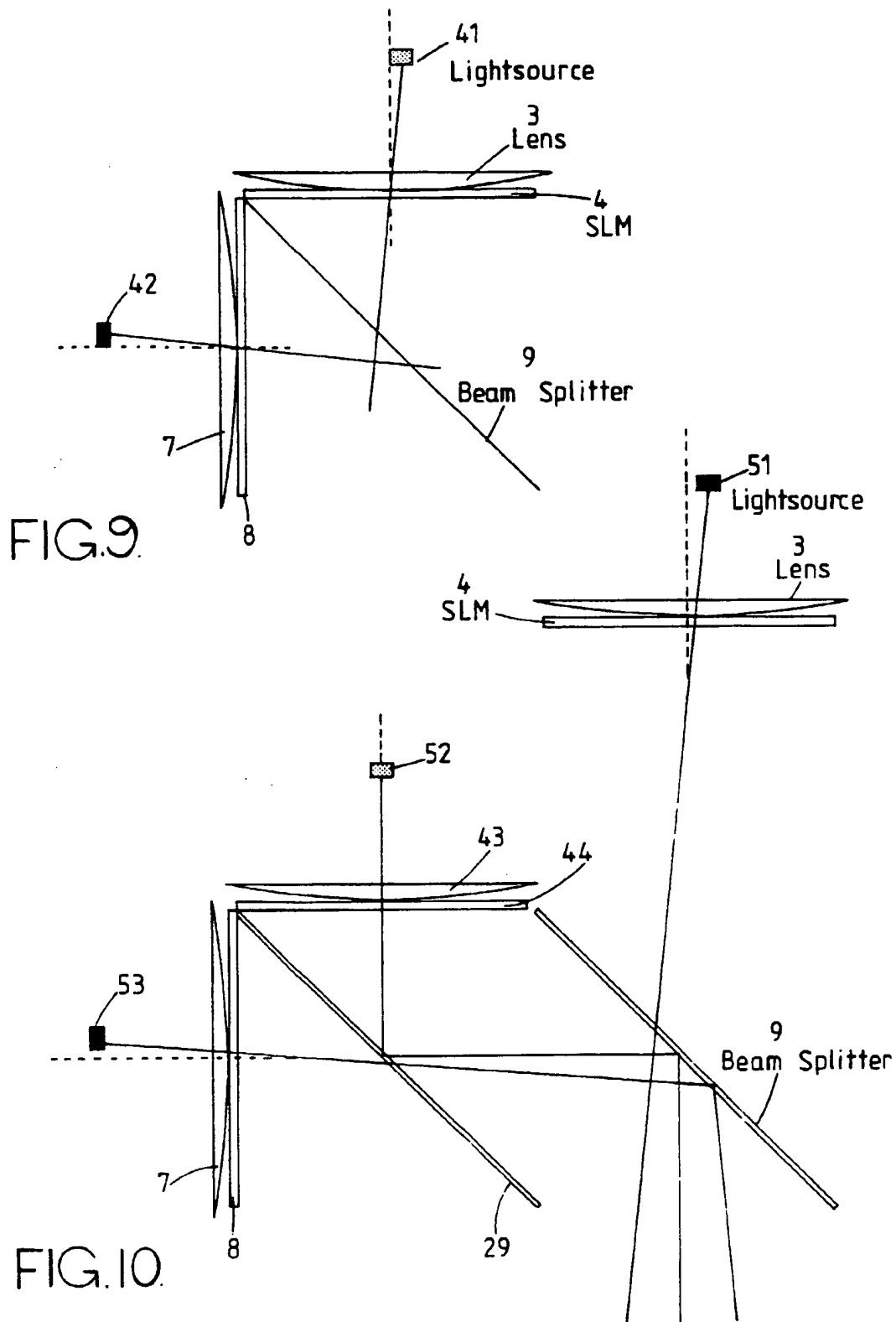


FIG.8.



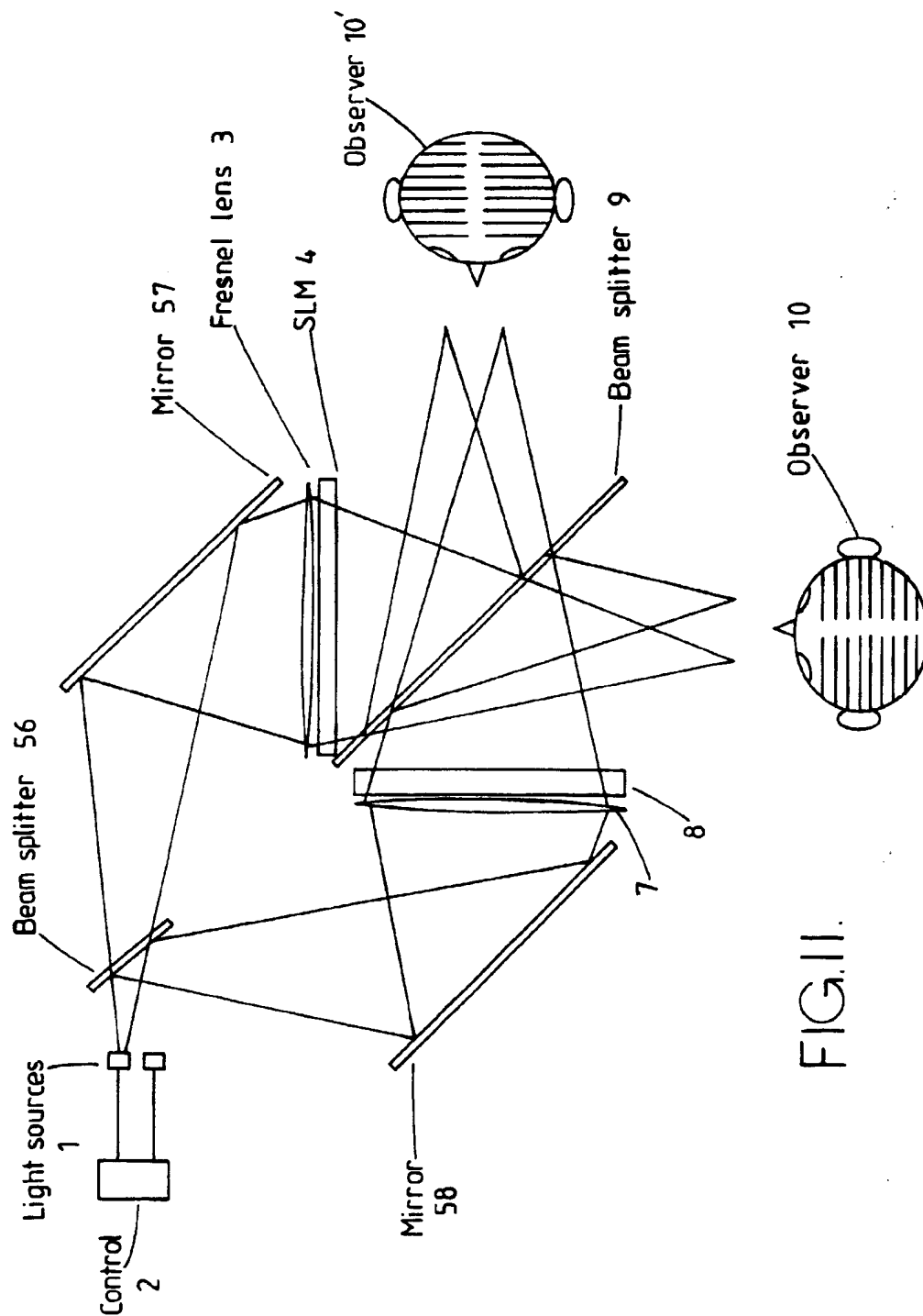


FIG. II.

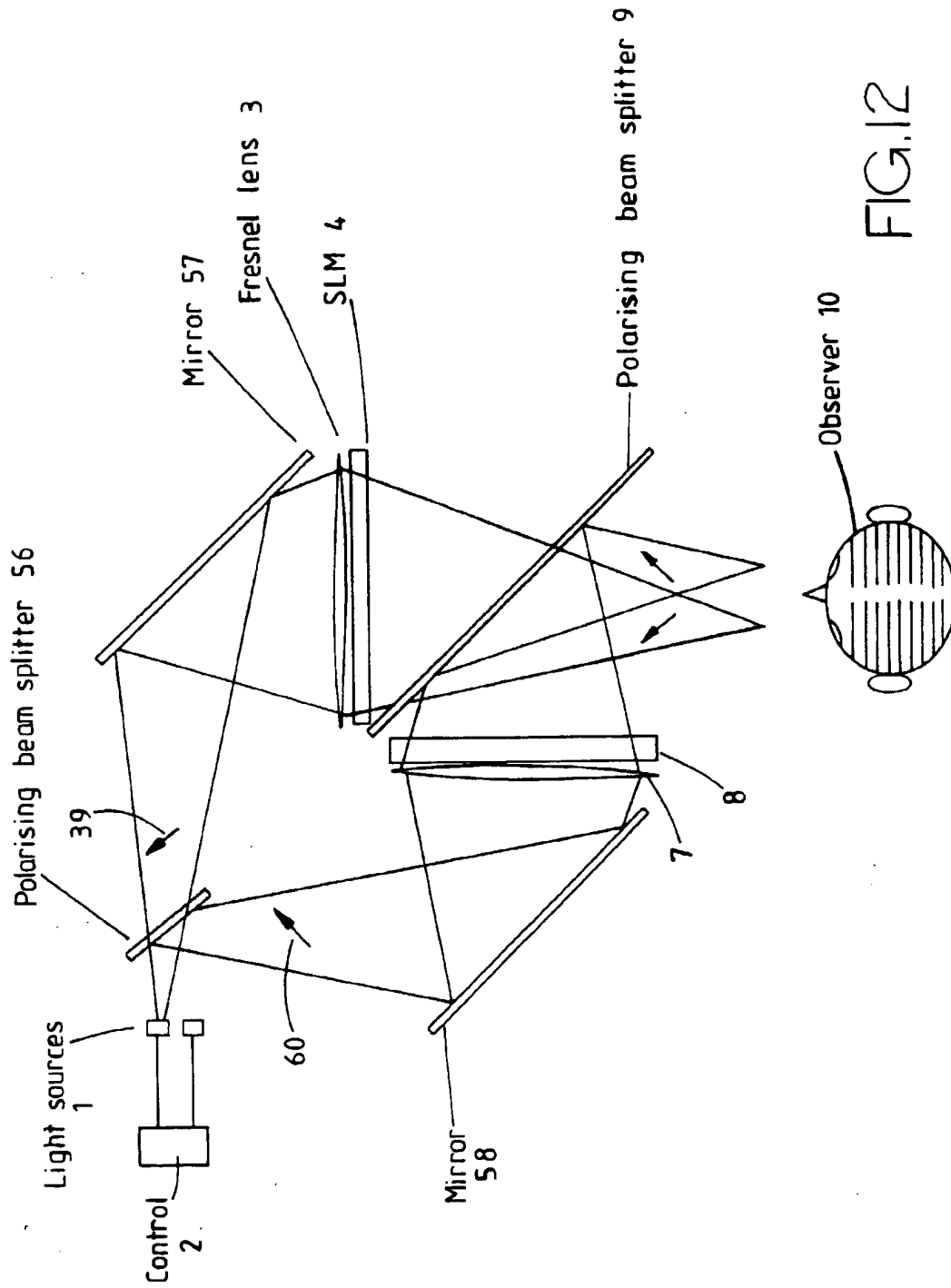
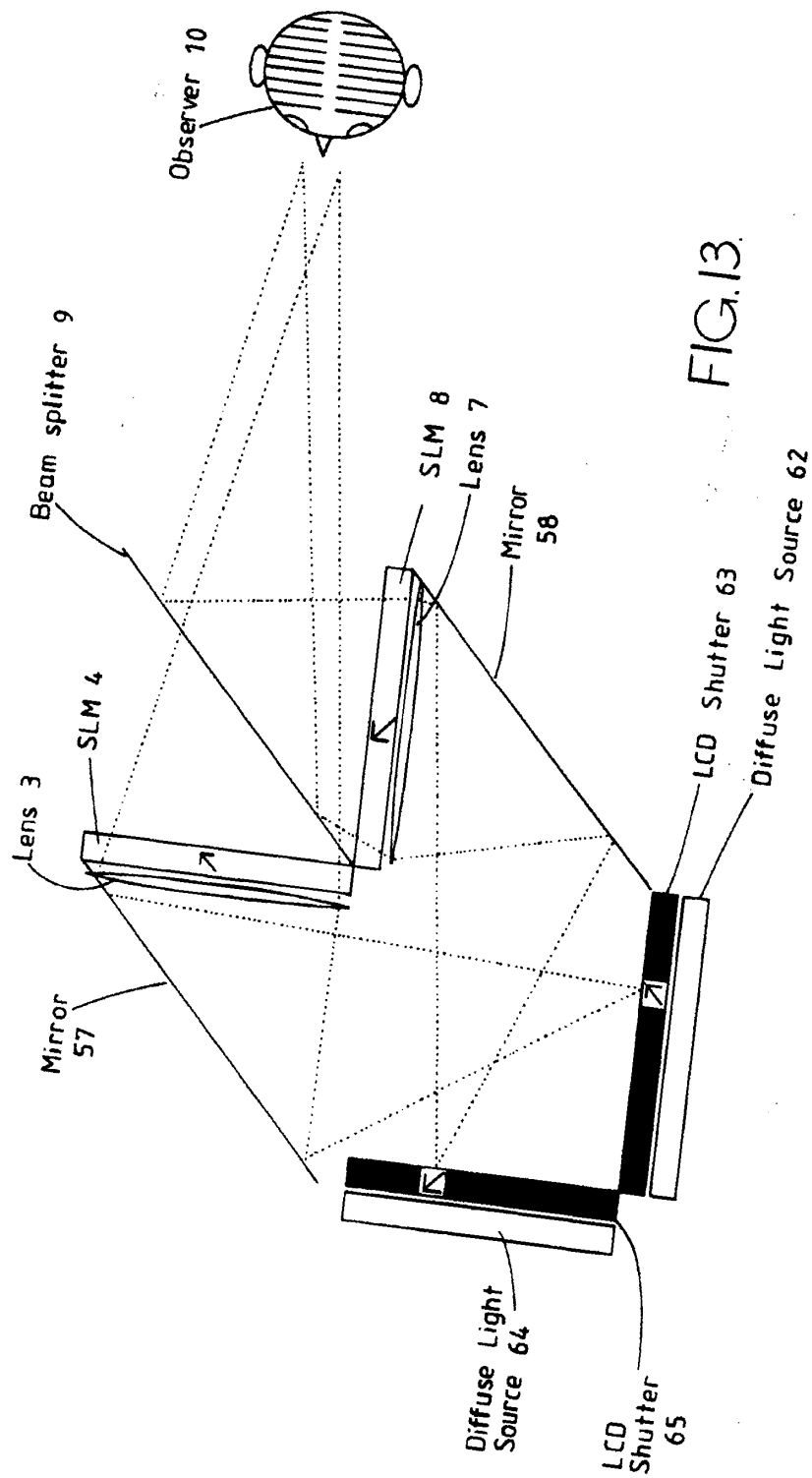


FIG. 12



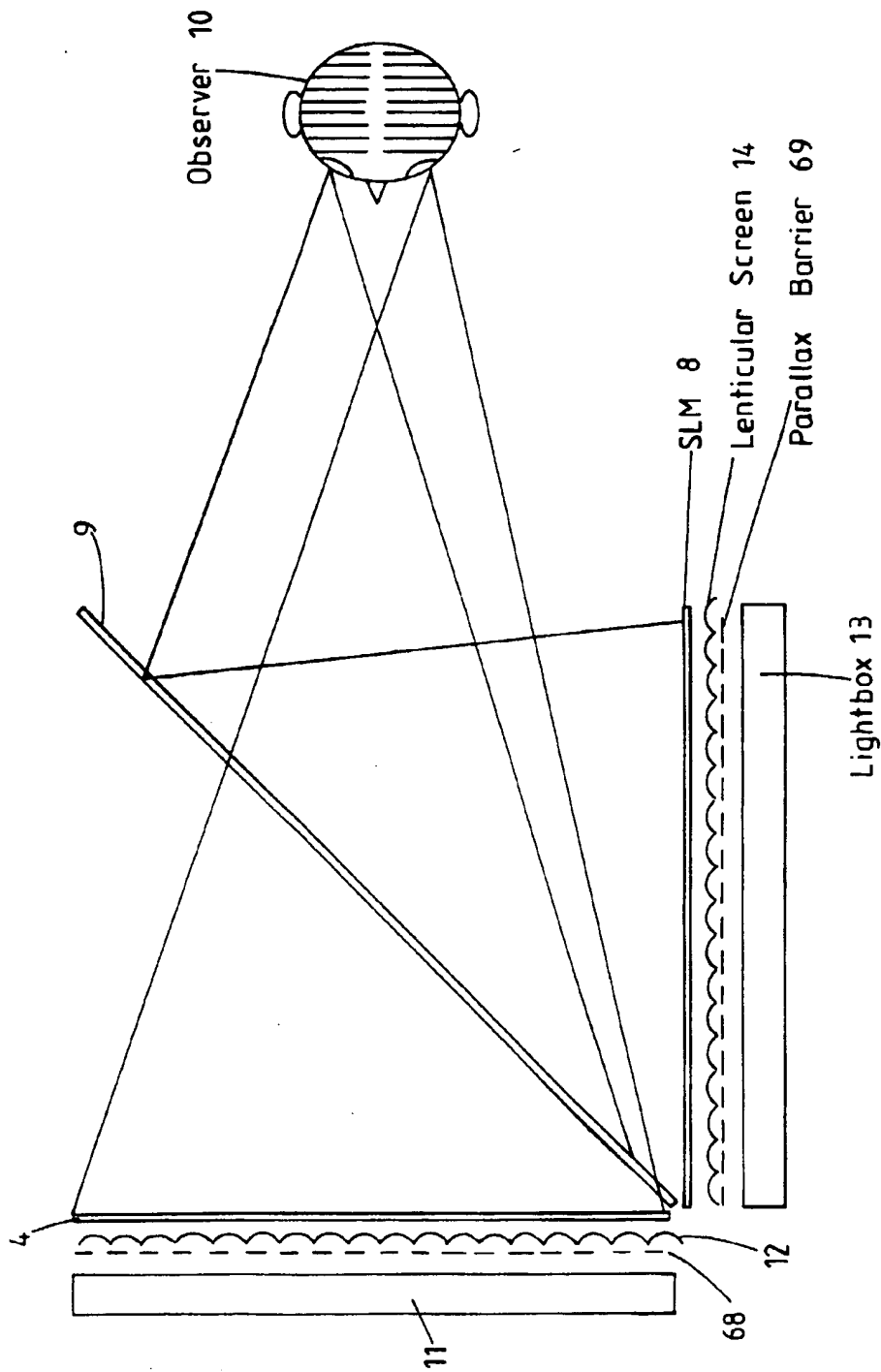


FIG.14.

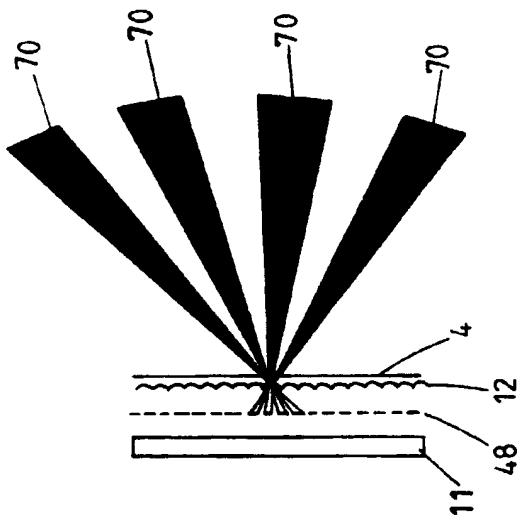


FIG. 15a.

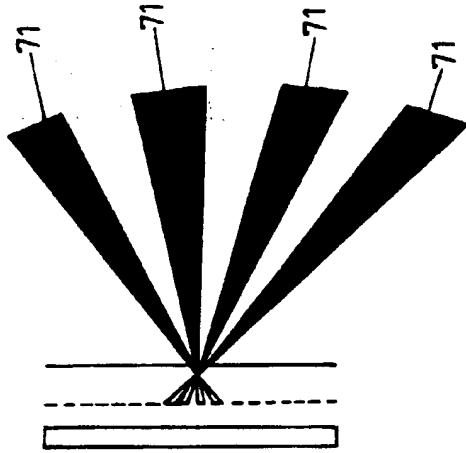


FIG. 15b.

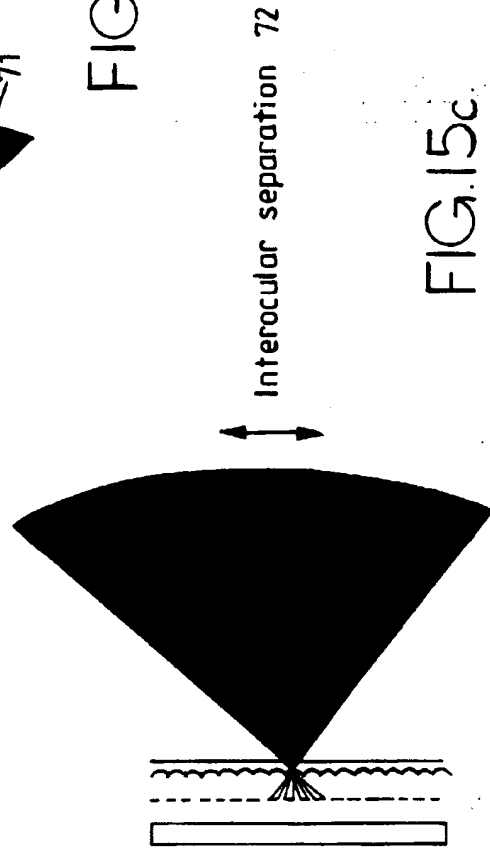


FIG. 15c.

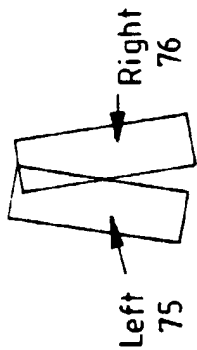


FIG. 16.

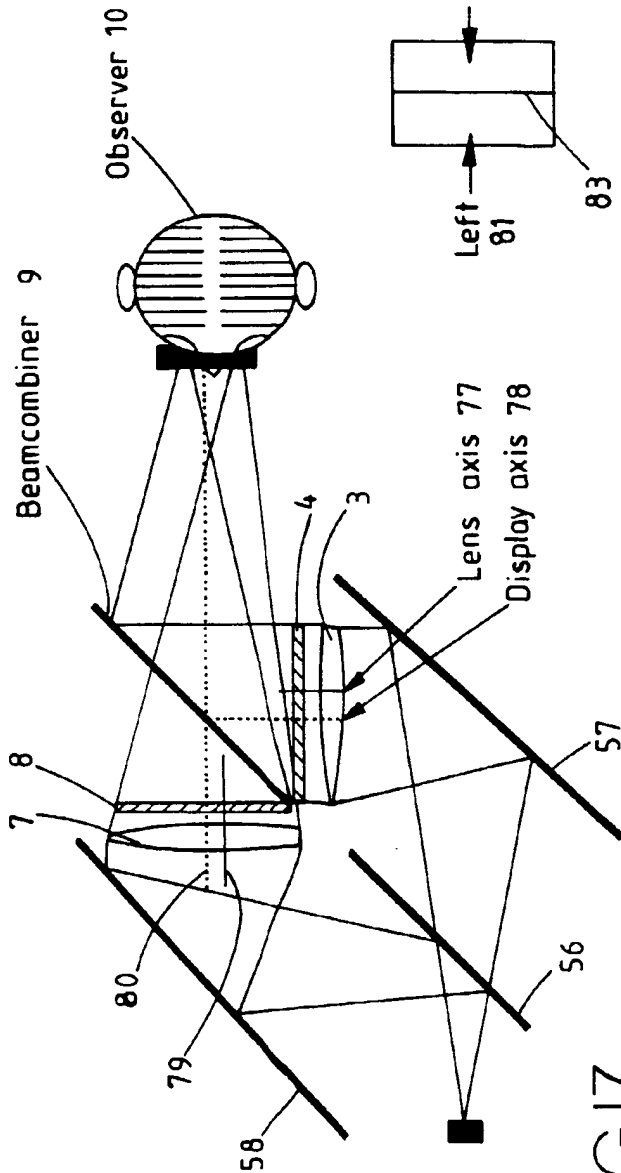


FIG. 17.

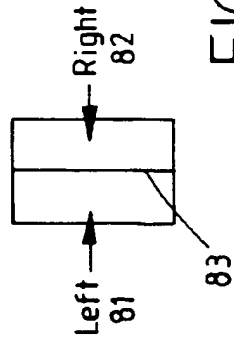
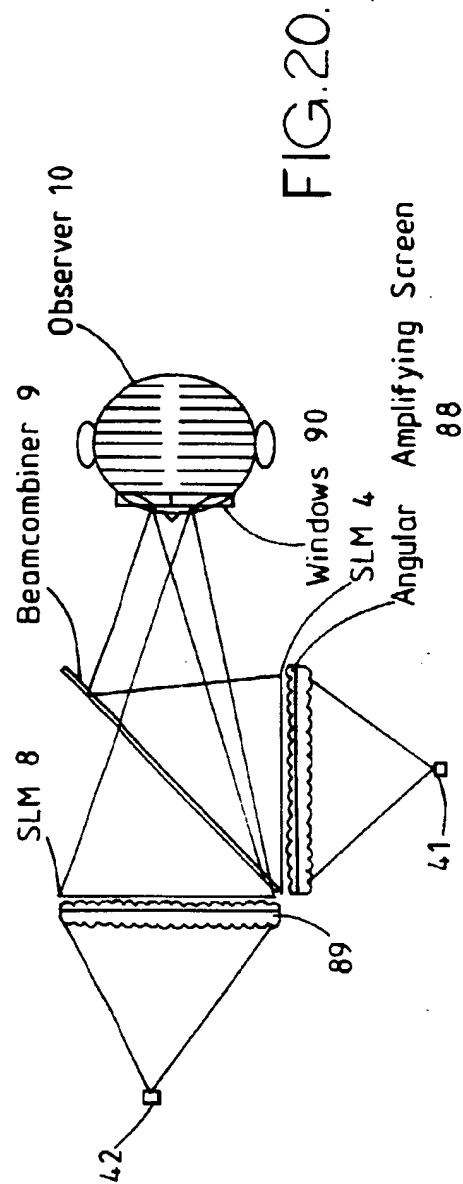
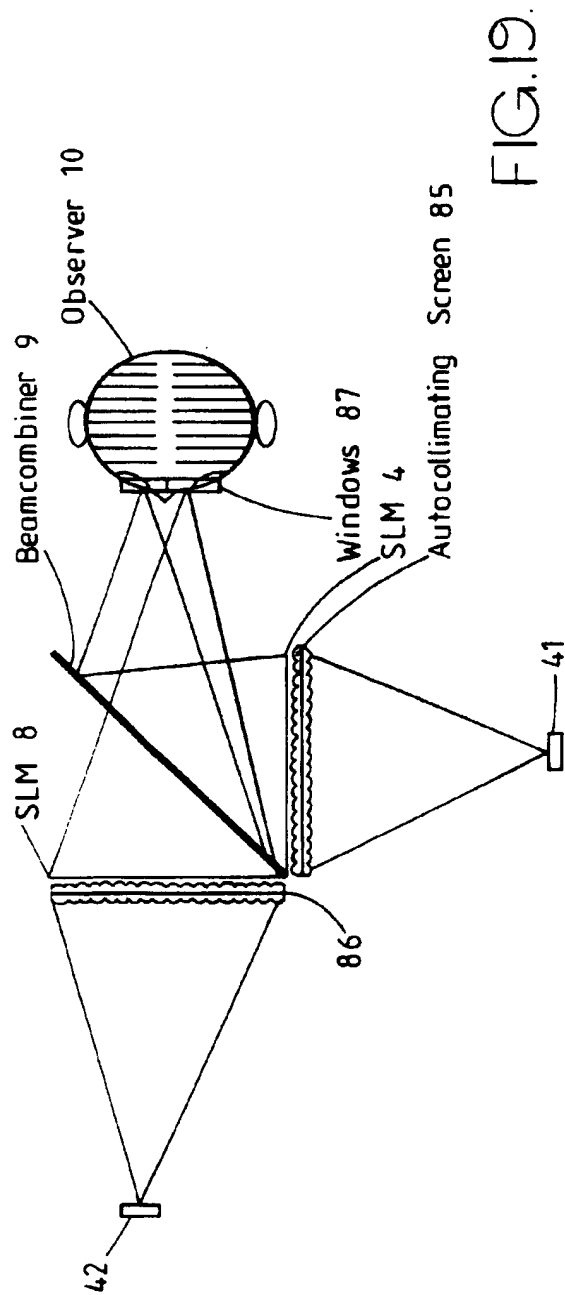


FIG. 18.



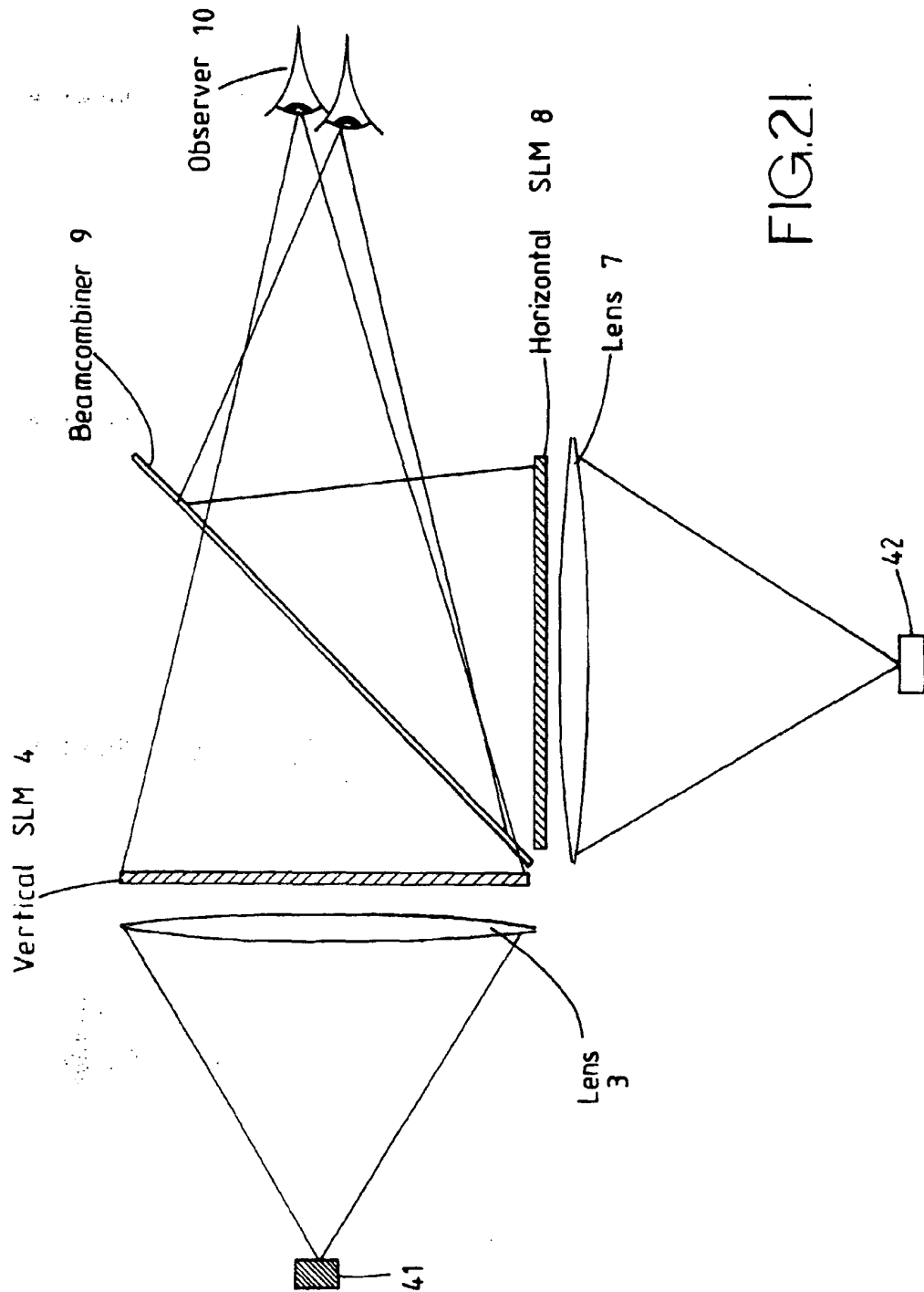


FIG. 21.

